Rectangle Surface Coil Array in a Grid Arrangement for Resonance Imaging

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***Abstract*—this paper deals with the development of vertical and horizontal rows of rectangle surface coils in a cross-hatching called "grid array." The purpose of this grid array is for unilateral resonance imaging. Each coil in the horizontal or vertical rows transmits and receives sequentially using switchable array configuration. The coils are tuned, matched, and decoupled to a 28.1MHz resonance using a "matchbox" pi-circuit with each coil. The results of this paper apply to quadrupole resonance imaging.**

***Index Terms*—surface coil, rectangular coil, coil array, switchable array, RF magnetic field, NQR, MRI, NMR, tuning, decoupling**

I. Introduction

RESONANCE imaging can be accomplished using Nuclear Magnetic Resonance (NMR) or Nuclear Quadrupole Resonance (NQR) techniques. REF [1] and [6] explain the differences between NMR and NQR. What NMR and NQR have in common are using coil arrays for unilateral surface detection and imaging. Most coil arrays for surface imaging are in a linear arrangement side-by-side and overlapping. Sometimes the coil arrays are in quadrants arrangements like REF [3] or in matrices like REF [2].

The issues coil arrays have for surface imaging are: too few coils in the array for good resolution image like the quadrant arrangement in REF [3], having many coils in the array arranged in a matrix-like grid with columns and rows, but coaxial cable for each coil are blocking the coil array surface area.

This investigation provides a solution to the issue by having multiple coils in a rectangular shape. These coils are side-by-side in one row vertical; then, a horizontal row on top of the vertical row. This will provide a vertical and horizontal resonance detection of the material sample in a matrix or grid arrangement, which is called "grid array." The coaxial cables will be on the ends of the coils and not blocking the area for surface imaging. This paper investigates how the coils are tuned, matched and decoupled for resonance imaging applications.

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II. Grid Array Development

The 4 x 4 grid array surface coils are developed by using 22 gauge magnet wires with insulating coating for rectangular surface coils. The wires are formed into four one turn 145mm x 32mm rectangular coils horizontal, and 128mm x 35mm coils vertical to form a cross-hatch coil grid. This grid array is taped to a HDPE plastic substrate that is 160mm x 148mm x 6mm for mechanical support and stabilization. The excess space on substrate is for the coaxial cable connections and tuning capacitors.

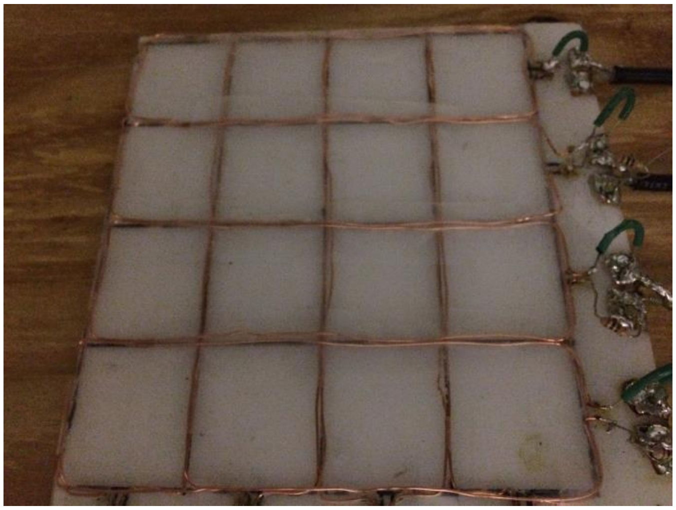

Fig.1, picture of horizontal and vertical array of rectangular surface coils 4 x 4.

Each surface coil has a coaxial cable soldered to two copper pads for electrical contacts. Fixed 10pF capacitors are placed in parallel with the coils to tune to a resonance frequency just above 74MHz, and have 10 ohm resistors in series with the coil to drop the Q low. The reason for the low Q is that all the rectangle surface coils have slightly different inductances due to physical dimensions. A wider bandwidth will insure all surface coils are individually tuned and matched within the bandwidth of resonance NQR frequency of 28.1MHz. The matching and tuning is explain in detail in the next section of this paper.

III. TUNING, MATCHING, AND DECOUPLING GRID ARRAY

The use of a “matchbox” circuit as in REF[2] is applied in this investigation since the surface coils are initially tuned above 74MHz and the rectangle coils are side-by-side each other and not overlapping. Since the positions of the coils were not overlapping, decoupling was achieved exclusively by different resonance frequencies of the passive and active elements. The matchbox shown in Fig. 2, has a pi-circuit with a series wound coil and two capacitors in parallel. The parallel capacitor for tuning, Ct, is 156pF, which drops the resonance frequency down to 28.1MHz from 74MHz. The parallel capacitor for matching, Cm, is 288pF, which matches the tuned coil to 50 ohms input impedance. This matchbox is manually moved from one coil to the next in the grid array. This achieves the switchable array configuration. Later, investigations will have circuit controlled multiplexer for switching to different coils.

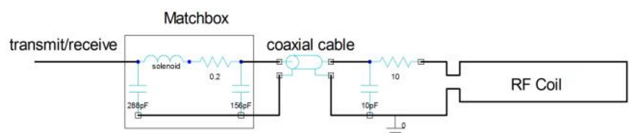

Fig.2, schematic diagram of active RF coil with matchbox connected.

All the coils in the grid array shown in Fig.3 were measured using an HP8753D Network Analyzer. The all the return loss were -21dB or better at 28.1MHz when the matchbox was attached.

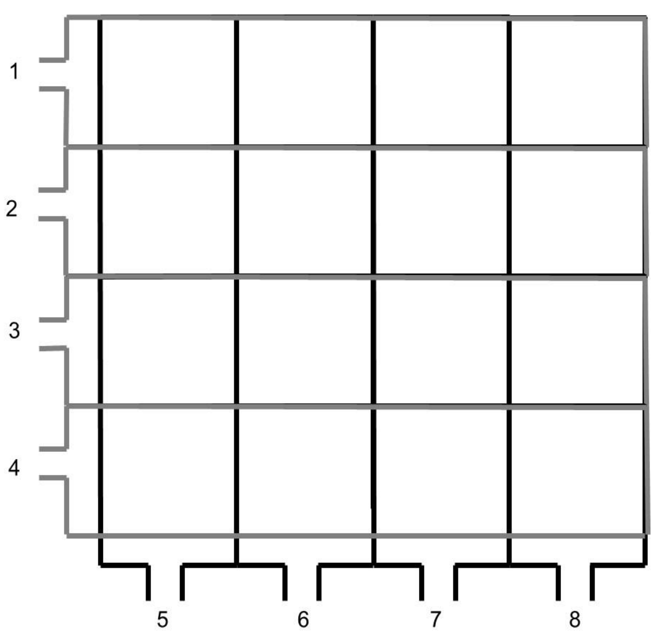

Fig.3, grid array arrangement diagram with matchbox connected to active coil

Mutual coupling was also measured with the network analyzer. The coils that are active (have the matchbox connected) are coils 1 and 5 in Fig.3. Mutual coupling or insertion losses were measured between active and inactive coils in each row. In the horizontal and vertical row of coils, mutual coupling is measured between an active coil on coil 1 and 5 and the next neighboring inactive coil 2 and 6. The insertion loss was -11.3dB at 28.1MHz. The next neighboring inactive coils 3 and 7 from the active coils had an insertion loss of -33dB at 28.1MHz. The insertion loss between active coils and coils 4 and 8 were below -40dB. The insertion loss between an active coil and an inactive coil perpendicular was so low that is was negligible.

IV. CONCLUSION

This investigation was done with a 4 x 4 grid array of rectangle surface coils, but is scalable to larger grid arrays. The risk of using rectangle coils with small width is the RF magnetic fields will not have a large standoff distance perpendicular to the coil surface. This limits the unilateral detection and imaging of the sample materials. Future research will investigate how the RF magnetic fields effect the quadrupole resonance signals.

V. REFERENCES

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